GEOTEST ENGINEERING, INC.

Geotechnical Engineers & Materials Testing

5600 Bintliff Drive Houston, Texas 77036 Telephone: (713) 266-0588
Fax: (713) 266-2977

Job No. 1140208301
Trench Safety Report
March 15, 2015

Mr. Shaheen Chowdhury, P.E., RPLS
Kuo & Associates, Inc.
10700 Richmond Avenue, Suite 113
Houston, Texas 77042

Reference: Trench Safety Design Considerations
Water Line Replacement in
Innsdale Area
WBS No. S-000035-0206-4
Houston, Texas

Dear Mr. Chowdhury:

We are pleased to present our geotechnical information for trench safety for the referenced project.

For trench excavation, it is essential to maintain the stability of the sides and base and not to disturb the soil below the excavation grade. This is necessary to prevent any damage to adjacent facilities as a result of either vertical or lateral movements of the soil. In addition, a satisfactory excavation procedure must include an adequate construction dewatering system to lower and maintain the water level at least 3 feet below the lowest excavation grade or a minimum of 5 feet below prevailing level of backfill during backfilling. This will minimize the potential for softening or "boiling" of the base support soil.

Trench Excavation (Auger Pits)

Based on the information provided by Kuo & Associates, Inc., it is understood that the water line replacement will be by trenchless method of construction. The following subsections provide information for the design and construction of the water lines and the excavations required for the proposed auger pits installation.

Geotechnical Parameters. Based on the soil conditions revealed by the borings GB-1 through GB-58, geotechnical parameters were developed for the design of auger pits

construction as part of the water line replacement. The design parameters are provided in Table 1. For design, the groundwater level should be assumed to exist at the ground surface.

Excavation Stability (Auger Pits). The open excavation may be shored or laid back to a stable slope or supported by some other equivalent means used to provide safety for workers and adjacent structures, if any. The excavating operations should be in accordance with OSHA Standards, OSHA 2207, Subpart P, latest revision and the City of Houston Standard Specification.

- Excavation Shallower Than 5 Feet - Excavations that are less than 5 feet deep **(critical height)** should be effectively protected when an indication of dangerous ground movement is anticipated.

- Excavations Deeper Than 5 Feet - Excavations that are deeper than 5 feet should be sloped, shored, sheeted, braced or laid back to a stable slope or supported by some other equivalent means or protection such that workers are not exposed to moving ground or cave-ins. The slopes and shoring should be in accordance with the trench safety requirements as per OSHA Standards. The following items provide design criteria for excavation stability.

  (i) OSHA Soil Type. Based on the soil conditions revealed by borings drilled for this study and assumed groundwater level at surface, OSHA soil type "C" should be used for determination of allowable maximum slope and/or the design of shoring along the alignment for full proposed depth of open excavation. For shoring deeper than 20 feet (if needed), an engineering evaluation is required and deeper soil borings will be needed.

  (ii) Excavation Support Earth Pressure. Based on the subsurface conditions indicated by our field investigation and laboratory testing results, excavation support earth pressure diagrams were developed and are presented on Figures 1.1 through 1.3. These pressure diagrams can be used for the design of temporary trench bracing. For a trench box, a lateral earth pressure resulting from an equivalent fluid with a unit weight of 94 pcf can be used. The effects of any surcharge loads at the ground surface should be added to the computed lateral earth pressures. A surcharge load, q, will typically result in a lateral load equal to 0.5 q. The above

value of equivalent fluid pressure is based on assumption that the groundwater level is near the ground surface, since these conditions may exist after a heavy rain or flooding.

(iii) Bottom Stability. In braced cuts, if tight sheeting is terminated at the base of the cut, the bottom of the excavation can become unstable. The parameters that govern the stability of the excavation base are the soil shear strength and the differential hydrostatic head between the groundwater level within the retained soils and the groundwater level at the interior of the trench excavation. For cut in cohesive soils as predominantly encountered for the proposed excavation depths in most of the borings, the bottom stability can be evaluated as outlined on Figure 2. However, at locations near borings GB-16C, GB-22B, GB-23, GB-24, GB-26, GB-50A, GB-52A, GB-53A, GB-54A, GB-55, GB-56C and GB-58 where cohesionless soils (such as silty sand, clayey sand and fine sand with silt) were encountered between depths of 0 and 23 feet (at invert or within 3 feet of bottom of excavation), dewatering will be necessary to avoid bottom stability problems, if excavation are planned during or after a heavy rainfall season.

Groundwater Control. Excavations for the water line may encounter groundwater seepage to varying degrees depending upon the groundwater conditions at the time of construction and the location and depth of the trench.

In general, for cohesive soils as predominantly encountered for most of the borings for the excavation depths, the groundwater if encountered may be managed by collection in excavation bottom sumps for pumped disposal. However, in borings GB-16C, GB-22B, GB-23, GB-24, GB-26, GB-50A, GB-52A, GB-53A, GB-54A, GB-55, GB-56C and GB-58 where cohesionless soils were encountered at invert or within 3 feet of bottom of the excavation; dewatering will be required, if the excavation is planned during or after a heavy rainfall event. Dewatering such as vacuum well points up to 15 feet or deep wells with submersible pumps for excavation greater than 15 feet may be required to lower the groundwater level to at least 5 feet below the bottom of the excavation (auger pits). It is recommended that the actual groundwater conditions should be verified by the contractor at the time of construction and that groundwater control should be performed in general accordance with the City of Houston Standard Specifications, Section 01578.

The range of cohesionless soils as encountered in the borings are given below:

Boring No.	Location/Street	Range of Depth of Cohesionless Soils Encountered, ft.		Soil Type
		From	To	
GB-16C	McGallion	8	13.5	Fine Sand with silt
GB-22B	Turner	10.5	18	Silty Sand
GB-23	Goldcrest	10	19	Silty Sand
GB-24	Goldcrest	8	13.5	Fine Sand with silt
GB-26	Cravens	10	13	Silty Sand
GB-43B	Firnat	12	14	Clayey Sand
GB-50A	Duff	12	23	Silty Sand
GB-51		0	2	Silty Sand
GB-52A		12	15	Silty Sand
GB-53A	Hendricks	12	20	Silty Sand
GB-54A		10	12	Silty Sand
GB-55	Hector	10	20	Silty Sand
GB-56C		10	15	Silty Sand
GB-58	Exeter	0	4	Silty Sand
		10	12	Clayey Sand

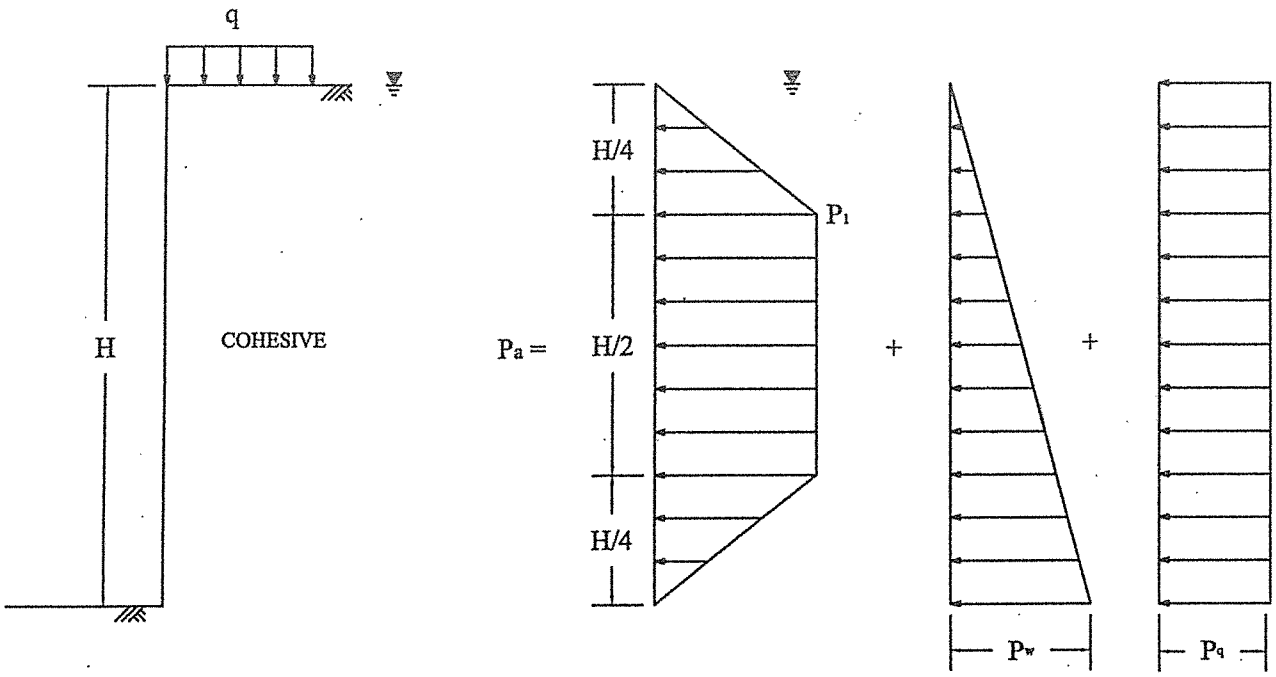
We appreciate this opportunity to be of service to you. If you have any questions regarding the report, or if we can be of further service to you, please call us.

Sincerely,
GEOTEST ENGINEERING, INC.
TBPE Registration No. F-410

Naresh Kolli, P.E.
Assistant Project Manager

NK\ego
Copies Submitted: (2)
Enclosures: Trench Support Earth Pressure – Figures 1.1 thru 1.3
Stability of Bottom for Braced Cut – Figure 2
Geotechnical Design Parameter Summary: Open-cut Excavation – Table 1
PC38\GEOTECHNICAL\40208301-TS.DOC

Job No. 1140208301



TYPICAL SOIL PARAMETERS

See Table 1 for typical values of soil parameters

BRACED WALL

For $\gamma H/c \leq 4$

$P_1 = 0.3\ \gamma_c' H$
$P_w = \gamma_w H = 62.4 H$
$P_q = 0.5\ q$

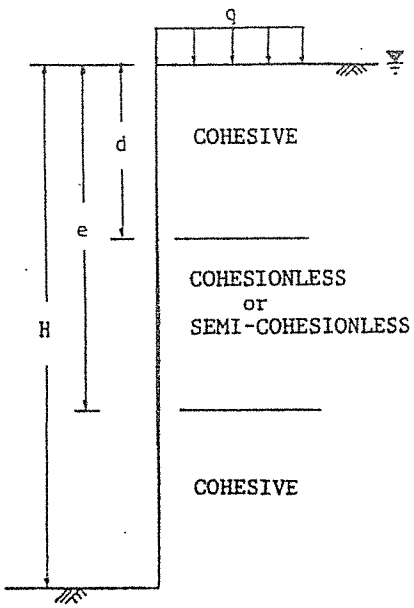
Where:

γ_c' = Submerged unit weight of cohesive soil, pcf;
γ_w = Unit weight of water, pcf;
q = Surcharge load at surface, psf;
P_a = Lateral pressure, psf;
P_1 = Active earth pressure, psf;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Depth of braced excavation, feet
c = Shear strength of cohesion soil, psf;

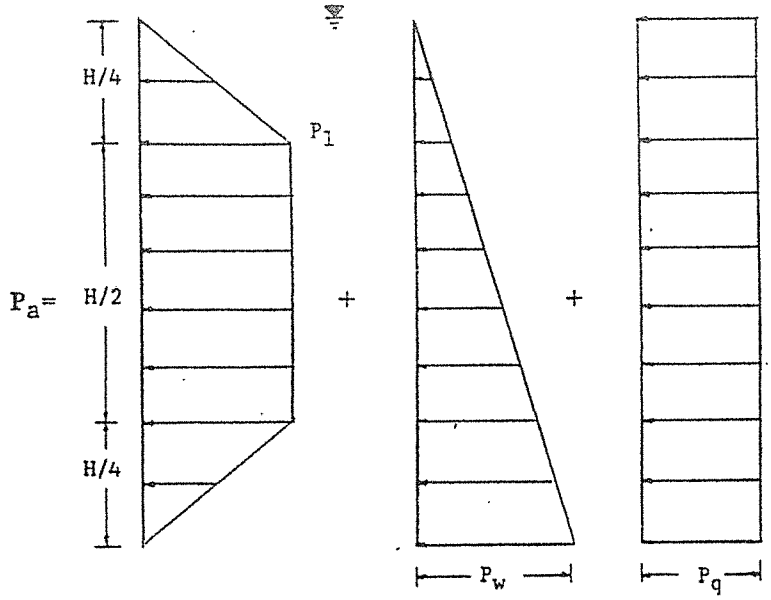
TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL

Job No. 1140208301



TYPICAL SOIL PARAMETERS



BRACED WALL

See Table 1 for typical values of soil parameters

$$P_1 = 0.3\ \gamma'_{avg}\ H$$

$$P_w = \gamma_w\ H = 62.4\ H$$

$$P_q = 0.5q$$

$$\gamma'_{avg} = \frac{\gamma_c'\ d + \gamma_s'\ (e-d) + \gamma_c'\ (H-e)}{H}$$

$$\gamma_w = 62.4\ pcf$$

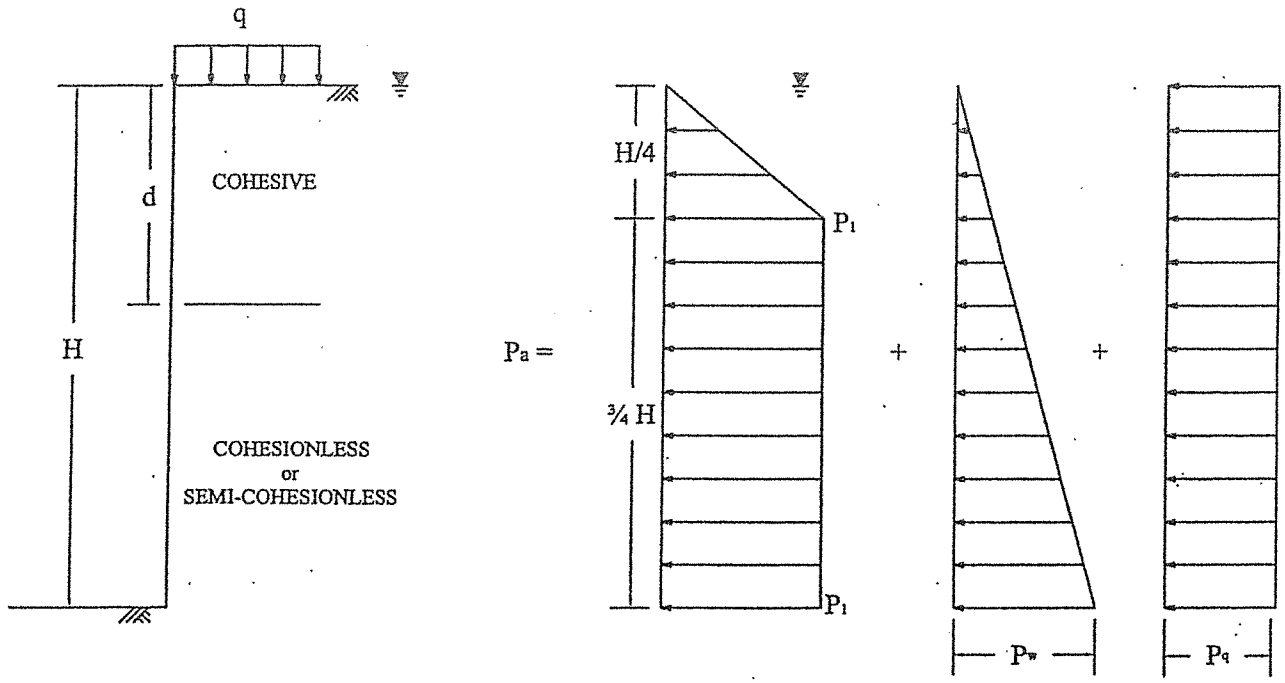
Where:

- γ_c' = Submerged unit weight of cohesive soil, pcf ;
- γ_s' = Submerged unit weight of cohesionless or semi-cohesionless soil, pcf ;
- γ_w = Unit weight of water, pcf;
- γ'_{avg} = Average submerged unit weight of soil, pcf ;
- q = Surcharge load at surface, psf;
- P_a = Lateral pressure, psf;
- P_1 = Active earth pressure, psf;
- P_q = Horizontal pressure due to surcharge, psf;
- P_w = Hydrostatic pressure due to groundwater, psf;
- H = Depth of braced excavation, feet

TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL INTERBEDDED WITH COHESIONLESS OR SEMI-COHESIONLESS SOIL

Job No. 1140208301



TYPICAL SOIL PARAMETERS

See Table 1 for typical values of soil parameters

$$\gamma'_{avg} = \frac{\gamma_c' \, d + \gamma_s' \, (H-d)}{H}$$

BRACED WALL

$P_1 = 0.3 \, \gamma'_{avg} \, H$
$P_w = 62.4 \, H$
$P_q = 0.5 \, q$

Where:

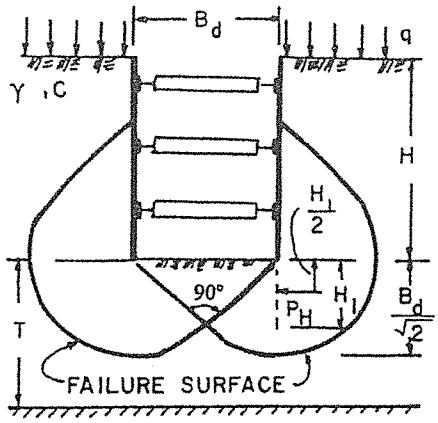
γ_c' = Submerged unit weight of cohesive soil, pcf;
γ_s' = Submerged unit weight of cohesionless soil, pcf;
γ'_{avg} = Average submerged unit weight of soils, pcf;
q = Surcharge load at surface, psf;
P_a = Lateral pressure, psf;
P_1 = Active earth pressure, psf;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Depth of braced excavation, feet

TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL OVER
COHESIONLESS OR SEMI-COHESIONLESS SOIL

Job No. 1140208301

CUT IN COHESIVE SOIL,
DEPTH OF COHESIVE SOIL UNLIMITED ($T > 0.7\ B_d$)
L = LENGTH OF CUT



If sheeting terminates at base of cut:

$$\text{Safety factor, } F_S = \frac{N_C C}{\gamma H + q}$$

N_C = Bearing capacity factor, which depends on dimensions of the excavation : B_d , L and H (use N_C from graph below)

C = Undrained shear strength of clay in failure zone beneath and surrounding base of cut

γ = Wet unit weight of soil (see Table 1)

q = Surface surcharge (assumed q = 500 psf)

If safety factor is less than 1.5, sheeting or soldier piles must be carried below the base of cut to insure stability - (see note)

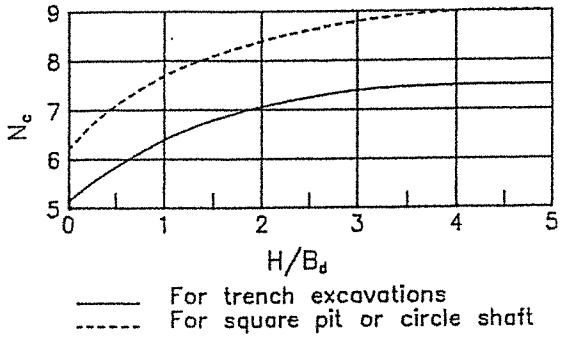
H_1 = Buried length $= \frac{B_d}{2} \geq 5$ feet

Note : If soldier piles are used, the center to center spacing should not exceed 3 times the width or diameter of soldier pile .

Force on buried length, P_H:

If $H_1 > \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 0.7\ (\gamma\ HB_d - 1.4CH - \pi CB_d)$ in lbs/ linear foot

If $H_1 < \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 1.5H_1\ (\gamma\ H - \frac{1.4CH}{B_d} - \pi C)$ in lbs/ linear foot



STABILITY OF BOTTOM
FOR
BRACED CUT

TABLE 1

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION (AUGER PITS)

Alignments	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, pcf	Submerged Unit Weight, γ', pcf	Undrained Cohesion, psf	Internal Friction Angle, φ, degree
8" Water Line along Meta, Meadow Lea and Madie	GB-1 thru GB-4A	Cohesive	0-4 4-12 12-14 14-16 16-20	125 130 130 128 125	63 65 65 64 63	800 500 1,000 400 1,500	-- -- -- -- --
12" Water Line along Bauman	GB-5A, GB-6 and GB-7	Cohesive	0-4 4-15 15-20 (GB-6 & GB-7 only)	125 128 124	63 64 62	800 900 1,000	-- -- --
8" Water Line along Burbank	GB-8 and GB-9	Cohesive	0-4 4-12 12-15	125 128 125	63 64 63	600 1,000 1,500	-- -- --
8" Water Line along Highlawn	GB-10 and GB-11	Cohesive	0-4 4-10 10-20 (GB-11 only)	125 130 128	63 65 64	800 1,500 1,400	-- -- --
8" Water Line along Luther	GB-12 and GB-13	Cohesive	0-8 8-10 10-12 12-15	125 132 128 124	63 66 64 62	800 1,000 500 2,000	-- -- -- --
8" Water Line along Wynell Terrace	GB-14	Cohesive	0-4 4-6 6-15	125 128 130	63 64 65	1,000 1,500 2,100	-- -- --
8" Water Line along McGallion	GB-15, GB-17, GB-18, GB-19A, GB-20 and GB-21	Cohesive	0-6 6-14 14-20 (GB-15 & GB-19A only)	115 122 118	58 61 59	800 1,000 2,000	-- -- --
	GB-16B and GB-16C	Cohesive Cohesionless Cohesive	0-8 8-13.5 13.5-15	125 116 125	63 58 63	600 -- 1,000	-- 30 --
8" Water Line along Turner	GB-22B and GB-23	Cohesive Cohesionless Cohesive	0-10 10-18 18-20	128 105 125	64 53 63	1,000 -- 1,000	-- 30 --
8" Water Line along Goldcrest	GB-24	Cohesive Cohesionless Cohesive	0-8 8-13.5 13.5-15	135 115 125	68 56 63	1,200 -- 1,000	-- 25 --
	GB-25 and GB-27	Cohesive	0-4 4-6 6-10 10-12 12-15	120 125 127 127 125	60 63 64 64 63	1,000 400 1,200 500 1,400	-- -- -- -- --

TABLE 1 (cont'd)

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION (AUGER PITS)

Alignments	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, Pcf	Submerged Unit Weight, γ', pcf	Undrained Cohesion, psf	Internal Friction Angle, φ, degree
8" Water Line along Cravens	GB-26	Cohesive	0-4	130	65	1,000	--
			4-6	120	60	1,500	--
			6-10	125	63	400	--
		Cohesionless	10-13	104	52	--	25
		Cohesive	13-15	120	60	1,600	--
	GB-27, GB-28 and GB-29	Cohesive	0-4	120	60	1,200	--
			4-6	120	60	400	--
			6-10	128	64	1,200	--
			10-12	126	63	500	--
			12-15	125	63	800	--
8" Water Line along Melrose	GB-30	Cohesive	0-4	125	63	1,000	--
			4-15	130	65	2,000	--
8" Water Line along Hurley	GB-31 and GB-32	Cohesive	0-4	125	63	1,000	--
			4-10	120	60	1,800	--
			10-15	118	59	1,000	--
8" Water Line along Pennington	GB-33, GB-34 and GB-35	Cohesive	0-4	125	63	1,000	--
			4-12	120	60	1,500	--
			12-15	126	63	400	--
			15-20 (GB-33 only)	127	64	500	--
8" Water Line along Hohl	GB-36 and GB-37	Cohesive	0-4	120	60	500	--
			4-10	122	61	1,800	--
			10-15	130	65	1,500	--
8" Water Line along DeBoll	GB-38, GB-39A and GB-40	Cohesive	0-6	125	63	500	--
			6-15	130	65	1,000	--
8" Water Line along Firnat	GB-41, and GB-42A	Cohesive	0-6	125	63	1,000	--
			6-8	132	66	1,300	--
			8-10	132	66	2,000	--
			10-15	128	64	400	--
			15-20 (GB-41 only)	125	63	1,600	--
	GB-43B	Cohesive	0-4	125	63	1,000	--
			4-12	132	66	2,000	--
		Cohesionless	12-14	105	53	--	30
			14-20	120	60	500	--

TABLE 1 (cont'd)

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION (AUGER PITS)

Alignments	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, Pcf	Submerged Unit Weight, γ', pcf	Undrained Cohesion, psf	Internal Friction Angle, φ, degree
8" Water Line along Warner	GB-44	Cohesive	0-10 10-15	126 132	63 66	800 1,600	-- --
8" Water Line along Doverside	GB-45	Cohesive	0-8 8-15	130 130	65 65	1,000 1,500	-- --
8" Water Line along Helmers	GB-46A and GB-47	Cohesive	0-15 15-20 (GB-47 only)	128 130	64 65	1,000 2,000	-- --
8" Water Line along Duff	GB-47 through GB-49	Cohesive	0-4 4-15 15-20 (GB-47 only)	125 128 130	63 64 65	1,000 1,000 2,000	-- -- --
	GB-50A	Cohesive Cohesionless Cohesive	0-12 12-23 23-30	126 106 130	63 53 65	400 -- 3,000	-- 30 --
	GB-51 and GB-52A	Cohesive Cohesionless	0-4 4-10 10-12 12-15	125 125 125 105	63 63 63 53	1,000 300 500 --	-- -- -- 30
8" Water Line along Hendricks	GB-53A	Cohesive Cohesionless	0-12 12-20	132 106	66 53	500 --	-- 30
	GB-54A	Cohesive Cohesionless Cohesive Cohesionless	0-10 10-12 12-14 14-15	130 125 125 106	65 63 63 53	1,000 -- 1,000 --	-- 25 -- 30
8" Water Line along Hector	GB-55 and GB-56C	Cohesive Cohesionless	0-10 10-15 15-20 (GB-55 only)	132 102 102	66 51 51	1,000 -- --	-- 30 30
8" Water Line along Exeter	GB-57	Cohesive	0-6 6-15	130 130	65 65	1,000 1,500	-- --
	GB-58	Cohesionless Cohesive Cohesionless Cohesive	0-4 4-10 10-12 12-15	106 135 100 130	53 68 55 65	-- 1,000 -- 1,700	30 -- 30 --

Note: 1) Cohesive soils include Sandy Lean Clay, Lean Clay w/sand, Lean Clay, Fat Clay w/sand, and Fat Clay
2) Cohesionless soils include Silty Sand, Fine Sand with silt and Clayey Sand.